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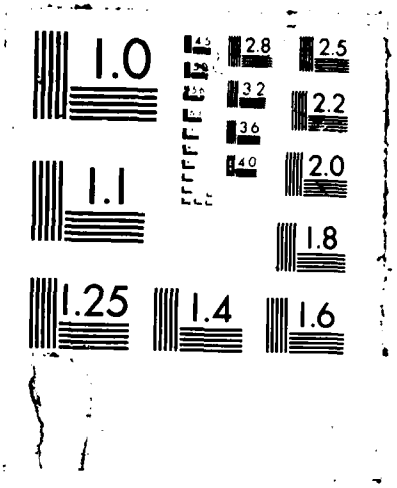
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Study for the Determination of General and Specific Properties of Wide Energy-Band Gap HgCdTe in the 1 to 2 Micrometer Wavelength Range.

Principal Investigator: A. Gauthier

Contractor: Societe Anonyme de Telecommunications

Contract Number: DAJA45-87-C-0020

1st Interim Report: July 1987 - September 1987

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Block 18 (continued): BAND GAP ENERGY VARIATION, IONIZATION COEFFICIENT, AVALANCHE PHOTODIODES

SUMMARY.

During this initial contract phase we concentrated on the study of physical properties of wide energy-band gap $Hg_{1-x}Cd_xTe$ on the one hand and on growth techniques for very high-grade material, on the other hand.

PHYSICAL PROPERTIES.

Variation of the energy-band gap E_g as a function of x-composition and temperature.

A precise relationship for $x > 0.5$ was established through optical transmission spectral response measurements, wherein:

$$E_g\ (x,T) = -0.303 + 1.94x - 0.655x^2 + 0.579x^3 + (5.5 - 13.92x + 5.84x^2)\ 10^{-4}\ T\ (eV)$$

The spectral region between 1 μm and 2 μm corresponds to x-values between 0.5 and 0.9. This relationship reveals a very small variation of E_g as a function of T (for example, for $x = 0.53$ we get $\frac{dE_g}{dT} = 2 \times 10^{-5}$ eV K^{-1}). This variation was confirmed through electro-reflectivity measurements between 35 K and 250 K.

Variation of the energy-band gap E_g and spin orbit coupling energy Δ_o as a function of x-composition.

Analysis of these two parameters discloses that the E_g/Δ_o ratio approaches 1 for $x = 0.6$.

This particular configuration imparts to the semiconductor some ionization properties which are quite interesting. There exists, in particular, a high ratio of ionization coefficients between holes and electrons ($K = \frac{\beta}{\alpha}$) which leads to a favorable condition in the design of low-noise avalanche photodiodes. This behavior has been experimentally confirmed for diodes operating at 1.55 μm , for which a noise figure of 2.3 was measured.

Intrinsic concentration.

Considering the low effective mass of the electrons in the conduction band, intrinsic concentrations remain low:

$n_i = 3 \times 10^{10} cm^{-3}$ for $x = 0.7$

$n_i = 2.8 \times 10^{8} cm^{-3}$ for $x = 0.9$

Mobility.

In the composition range between $x = 0.5$ and $x = 0.9$, electron mobility at 300 K on THM-grown samples confirmed values between 1,000 and 2,000 $cm^2 V^{-1} s^{-1}$. These results are in proper agreement with published literature.

Optical absorption.

Transmission measurements disclose a direct optical absorption coefficient between $10^3 cm^{-1}$ and $10^4 cm^{-1}$. A junction depth of a few microns is therefore adequate to absorb the total incident radiation.

MATERIAL GROWTH PROCESSES.

Stoichiometric growth methods (Bridgman, Quench Anneal, Slush or Zone Melting) developed for x <0.3 compositions are not applicable for the x >0.5 range because of the increased temperatures and excessively high mercury pressure.

Two types of metallurgy are presently developed:

- liquid or gas phase epitaxy: LPE, MOCVD, MBE, EDRI;
- solvent zone (Te) bulk growth: THM (Traveling Heater Method, developed by SAT).

Epitaxial processes.

- LPE (Liquid Phase Epitaxy).

  The layers are deposited on CdTe <111> or $Cd_{0.9}Zn_{0.1}Te$ substrates which form an adequate lattice match with the deposited layers. The growth temperature is between 550° and 600° C. The deposited layers are between 10 and 40 μm thick.

- VPE (Vapor Phase Epitaxy). Several methods have been developed:

  MOCVD: Metallorganic Chemical Vapor Deposition;

  MBE: Molecular Beam Epitaxy;

  EDRI: Isothermal Evaporation Diffusion.

  Growth temperatures range from 50°C (MBE) to 400-600°C (EDRI, MOCVD). Layers have been grown on CdTe and GaAs using MOCVD and MBE. The EDRI method, because of its implied interdiffusion process, requires only CdTe substrates.

It seems that the MOCVD process is presently the most promising method for multilayer deposition. The IMP (Interdiffused Multilayer Process) method permits the growth of homogeneous material.

Bulk growth process: THM (Traveling Heater Method).

As far as we know, only SAT and "Laboratoire de Physique des Materiaux" (CNRS, Bellevue) have published their results on the growth of wideband HgCdTe material. The material is grown in ingot form (40 mm diameter, 60 mm long). The material is synthesized at 700°C; the growth rate is 2.5 mm per day.

Longitudinal and radial homogeneity, as measured by optical transmission, show excellent results (longitudinal deviation: $\Delta\lambda < 0.1$ μm, radial deviation: $\Delta\lambda \ll 0.01$ μm). We are currently conducting a metallurgical investigation to obtain oriented, single-crystal ingots.

CONCLUSION

This initial effort demonstrates that the intrinsic properties of the material (low intrinsic concentration), the respective values of the band gap and spin-orbit energies and the small variation of the band gap energy as a function of temperature hold the key for the development of high performance receivers in the 1 to 2 μm wavelength region. Technical studies of the THM material growth method are well advanced and they already make available to us a high-grade material.

FUTURE PLANS

Our next effort will be directed to the following:

- investigation of the electroluminescent properties of the photodiodes and of their fabrication possibilities;

- the fabrication of the avalanche photodiodes which are to be delivered under this contract. These diodes will be fabricated from THM-grown material.

Appendix to First Interim Report (Contract DAJA45-87-C-0020)

Unused funds at the end of this report period: $ 122,500

No important property was acquired with contract funds during the period covered by this report.

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